Computation Of Cumulative Sound Exposure Impact Zone For Ketchikan Berth II Project

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1. Determine Source Level

Peak source levels of the confined blast are calculated based on Hempen *et al.*, (2007)

$$P = 1780 \times \left(\frac{d}{W^{1/3}}\right)^{-1.23} \quad (1)$$

where P is peak pressure in pounds per square inch (psi), d is distance in feet, and W is weight in pounds. For source level calculation

d = 4 or 6 ft
W = 75 lb for a single charge

Note: The total charge weight is defined as the product of the single charge weight and the number of charges. In the case of Ketchikan Berth II Project, the number of charges is 50.

2. Explosive Energy Computation from Peak Pressure of the Single Maximum Charge

For plane wave, the energy density can be expressed as (Urick, 1983; Kinsley *et al.*, 2000)

$$E = \frac{1}{\rho c}\int_0^\infty p^2(t)\,\mathrm{d}t \quad (2)$$

where ρc is the characteristic impedance of the medium (seawater).

For underwater explosives, it is found that the shock wave, expressed as a relationship between pressure and time (t), can be approximated by (Urick, 1983)[1]:

[1] The decay function can be updated based on the waveform of a detonation, if provided.

$$p\left(t\right) = Pe^{-t/t_0} \tag{3}$$

where P is the initial pressure of the shock wave at $t = 0$, and t_0 is the time constant when the shock pressure decays to $1/e$ of its initial value P, with unit of microsecond (Urick, 1983):

$$t_0 = 58W^{1/3} \times \left(\frac{W^{1/3}}{r}\right)^{-0.22} \tag{4}$$

where r is the range in feet.

3. Summation of Total Explosive Energy from All Charges

Due to time and spatial separation of each single charges by a distance of 8 ft, the accumulation of acoustic energy is added sequentially, assuming the transmission loss follows cylindrical spreading within the matrix of charges.

$$E_{\text{total}} = \sum_{n=1}^{N} E_n \tag{5}$$

where E_{total} is the total acoustic energy from all charges, E_n is the acoustic energy from the nth charge in the matrix, and N is the total number of charges.

The sound exposure level (SEL) from each charge at its source can be calculated by

$$SEL = 10\log_{10}\frac{E}{E_{ref}} \tag{6}$$

where $E_{ref} = 6.76 \times 10^{-19}$ W/m^2.

The received sound exposure level (SEL_{rec}) from each charge can be calculated using the sonar equation:

$$\begin{aligned} SEL_{rec(n)} &= SEL - TL_n \\ TL_n &= 10\log_{10} R_n \end{aligned} \tag{7}$$

where SEL is the sound exposure level at the source in Equation (6), and $SEL_{rec(n)}$ is the received sound exposure level at a given point from charge n located at distance R_n, and TL_n is the transmission loss of acoustic energy due to cylindrical spreading from the source over R_n.

Since the charges will be deployed in a grid of 8 ft by 8 ft apart, thus the received *SEL*s from different charges to a given point will vary depending on the distance of the charges. Without specific information regarding the layout of the charges, the modeling assumes a grid of 8 by 9 charges with an additional three charges located in the three arbitrary pareferal locations (Figure 1).

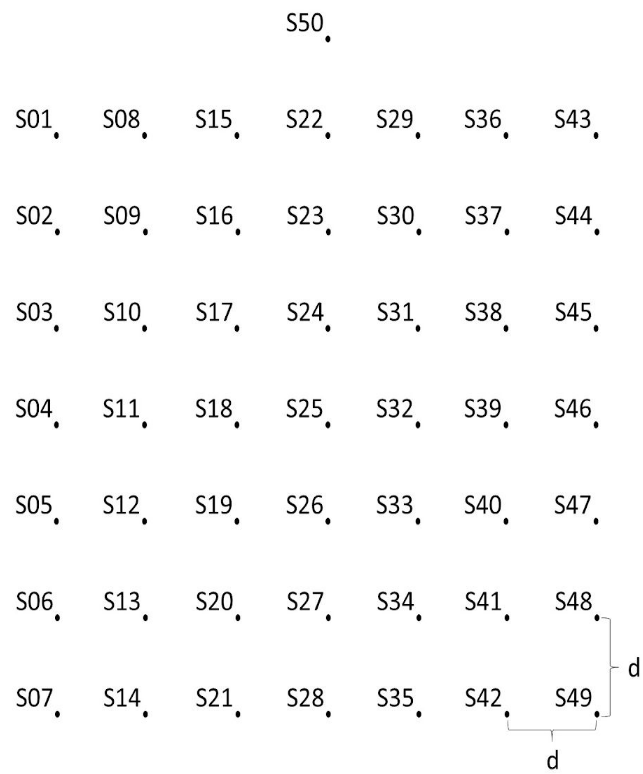

Figure 1 Schematic diagram of the charge layout for the Ketchikan Berth II project modeling. Each dot represents a location where a 75-lb charge is placed, separated by a distance d (either 4 or 6 feet).

The total sound exposure level ($SEL_{\text{total}(m)}$) at any given location m shown in Figure 1 can be calculated as

$$SEL_{\text{total}(m)} = 10 \log_{10} \sum_{n=1}^{N} 10^{\left(SEL_{rec(n)}/10\right)} \tag{8}$$

Among the various total sound exposure levels calculated by Equation (8), the largest value, $SEL_{\text{total(max)}}$ is selected to calculate the impact range.

4. Energy Spectral Analysis

Using the pressure versus time relationship in Equation (3), the frequency spectrum of the explosion can be computed by taking the Fourier transform of the pressure (Weston, 1960):

$$p(f) = \int_{-infty}^{infty} P e^{-t/t_0} e^{-i2\pi ft} \mathrm{d}t \tag{9}$$

Given that for a plane wave, the peak intensity can be expressed as

$$I_0 = \frac{P\bar{P}}{\rho c} \frac{2}{t_0} \tag{10}$$

where $\bar{P}$ is the complex conjugate of pressure P, the Fourier analysis for the energy spectrum of an exponentially decaying explosion can be shown as

$$I_0(f) = \frac{2P^2}{\rho c \left(\frac{1}{t_0^2} + 4\pi^2 f^2\right)} \tag{11}$$

where f is the frequency in Hz.

5. Transmission Loss from Sound Absorption

Frequency specific transmission loss of acoustic energy due to absorption is computed using the absorption coefficient, α (dB/km), summarized by François and Garrison (1982a, b):

$$\alpha(f) = \frac{A_1 P_1 f_1 f^2}{f^2 + f_1^2} + \frac{A_2 P_2 f_2 f^2}{f^2 + f_2^2} + A_3 P_3 f^2 \tag{12}$$

The three terms in Equation (12) refer to different absorption mechanisms due to boric acid, magnesium sulfate, and pure water, respectively. Details of parameters presented in Equation (12) are provided in François and Garrison (1982a, b). Seawater properties for computing sound speed and absorption coefficient were based on NMFS Alaska Fisheries Science Center report of mean measurements in Auke Bay (Sturdevant and Landingham, 1993).

6. Impact Range Calculation

The transmission loss that required for the received levels to reach below the specific $SEL_{\text{threshold}}$ threshold were calculated using the sonar equation:

$$TL = SEL_{\text{total(m)}} - SEL_{\text{threshold}} \tag{13}$$

where SEL_{threa} is the Level A harassment threshold of marine mammals.

The distances, R, where such transmission loss is achieved were computed numerically by combining both geometric transmission loss, TL_{geo}, and transmission loss due to frequency-specific absorption, TL_{abs}:

$$\begin{aligned} TL(f) &= TL_{\text{geo}} + TL_{\text{abs}} \\ &= 20\log_{10}(R) + \alpha(f)\frac{R}{1000} \end{aligned} \tag{14}$$

A spreading coefficient of 20 is assumed to account for acoustic energy loss from the sediment into the water column.

References

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